Appendix E
River Data for Initial Assessment Performed with the System Assessment Capability (Revision 0)

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1.0 Introduction

The objective of this appendix is to present the data assembled to model contaminant transport in the Columbia River for the initial assessment performed using the System Assessment Capability, Rev. 0. The package includes data required to model hydrodynamics (water velocities and water surface elevation), sediment transport, contaminant transport, biotic transport, sediment-contaminant interaction including suspended sediments and bed sediments in the Columbia River, and the material contributed by the Yakima, Snake and Walla Walla rivers. Design of the System Assessment Capability and a description of the initial assessment are presented in System Assessment Capability (Revision 0) Assessment Description, Requirements, Software Design and Test Plan (Kincaid et al. 2000). Background information on the development of the SAC is presented in Preliminary System Assessment Capability Concepts for Architecture, Platform and Data Management which can be found at http://www.bhi-erc.com/vadose/sac.htm#info.

2.0 Background

The analysis plan for Columbia River is presented in Kincaid et al. (2000). It identifies the approach to be taken to model contaminant transport in the river and discusses the types of data to be assembled to perform the initial assessment using SAC Rev. 0. This work has been completed.

The River Flow and Transport Module provides the capability to calculate the flow, sediment transport, and contaminant transport in the Columbia River system. The capability in the River Flow and Transport Module is provided by the legacy code MASS2 (Richmond, Perkins, and Scheibe 1999). MASS2 is a two-dimensional depth-averaged model that provides the capability to simulate the lateral (bank-to-bank) variation of flow and contaminants.

3.0 Interaction with other SAC Modules

The River Flow and Transport module will receive input from the groundwater module, the vadose zone module, and in the case of reactor discharges, directly from the inventory module. Stochastic variability of certain input parameters used by the River Flow and

Transport Module will be generated by the Environmental Stochastic Preprocessor. Contaminant and water influx from groundwater will be input to the bed sediment layer in MASS2 using output from the GWDROP Data Translator. MASS2 will generate and output annual average concentrations of contaminants in the water column (dissolved and total sediment –sorbed) and in the bed sediments (pore water and total sediment-sorbed). The CRDROP data translator will use MASS2 outputs to archive concentration information for use by the impacts modules.

The river shore environment module will estimate contaminant concentrations at locations (specified in the ESD to support impacts calculations) along the river shore on the Hanford Site. These concentrations will be derived from groundwater concentrations at the aquifer-river boundary computed by the groundwater flow module (CFEST96) and river water concentrations computed by MASS2.

The results of this modeling (concentrations in certain riparian media) will be stored in the ECDA files for use by the human, economic, cultural and ecological impacts modules.

4.0 Data Gathered

4.1 River Data

Data gathered for the river includes bathymetric data to define the shape of the river channel, river flow and stage data and distribution coefficient information. The distribution coefficient data describes the relationship between the amount of a contaminant sorbed on sediment and the amount of the contaminant dissolved in the water.

4.1.1 Bathymetry: Fine grid, coarse grid

The river bathymetry was generated from multiple data sources. Cross-sectional measurements were obtained from sediment surveys performed by the Corps of Engineers. Shorelines were digitized from recent air photos taken when flow in the river was 86,000 cubic feet per second. These elements were combined in ARC/INFO and a grid was generated containing 4 cells per cross section with an additional cell added at each incoming tributary (Yakima, Snake, Walla Walla). Such a coarse grid was necessary to minimize computing time and meet the run-speed requirements.

4.1.2 River Flows and Stages

Data on river discharges were obtained from USGS gage data. The Vernita Bridge, Kiona, and Burbank Gages were used for the Columbia, Yakima, and Snake River flows, respectively. Because of a gap in the Snake River data, some operations data at Ice Harbor Dam were used in addition to gage data. The water surface elevation of the McNary forebay was held at a constant 340 ft above mean sea level for all runs, which is the normal operating stage.

The performance of the hydraulic model component was assessed by comparison to Accoustic Doppler Current Profiler (ADCP) data collected by Greg Patton in numerous locations within the study reach.

4.1.3 Distribution Coefficient (K_d) Values

Distribution coefficient estimates for the linear sorption isotherm model are site specific because they are affected by numerous site specific characteristics including pH, salinity, substrate size and composition, substrate cation exchange capacity, the presence of organics, the concentrations of competing ions, and redox potential. Although many partition coefficient studies exist, most pertain to groundwater or marine environments with relatively few applying to freshwater, aquatic systems. Of those, even fewer apply to the sections of the Columbia River affected by the Hanford Site. We examined available data for studies that involved fresh water, aquatic environments, and basalt substrates. These data are summarized in Table 1 by source and substrate type. Few data were available for the aquatic environments of the Columbia River, so some estimates for local groundwater and some estimates for aquatic environments in other locations are included.

Table 1. Best, low and high estimates of K_d values (ml/g) for freshwater, aquatic or groundwater environments reported by substrate type.

			Sand			Silt			Clay			Organic			Unspecified	
Species	Source	Best	Low	High	Best	Low	High	Best	Low	High	Best	Low	High	Best	Low	High
CCl_4	Chen and Yaws (1999)										122					
Cs	Onishi (1980)					650	790		800	1000						
Cs	Sibley (1982)	600	390	829												
Cs	Gillham et al. (1980)		81	850	26000			4100								
Cs	Shell and Sibley (1982)													17	15	19
Cs	Sheppard and Thibault (1990)	280	0.2	10000				1900	37	31500	270	0.4	145000			
Cr	Sheppard and Thibault (1990)	70	1.7	1729				1500			270	6	2517			
I	Sheppard and Thibault (1990)	1	0.4	81				1	0.2	29	25	1.4	368			
Pu	Sheppard and Thibault (1990)	550	27	36000				5100	316	190000	1900	60	62000			
Pu	Sibley (1982)	12100	10700	30900												
Pu	Seymore et al. (1979)							285000	251000	319000						
Pu	Onishi (1980)							375	82	1091						4990

Sr	Onishi (1980)							787	660	950				1000		
Sr	Sibley (1982)	66.7	63.2	72												
Sr	Sheppard and Thibault (1990)	15	0.05	190				110	3.6	32000	150	8	4800			
Sr	Porro (2000)	3	2.37	4.26												
Tc	Sheppard and Thibault (1990)	0.1	0.01	16				1	1.16	1.32	1	0.02	340			
Tc	Onishi (1980)														0.007	2.8
U	Sheppard and Thibault (1990)	35	0.03	2200				1600	46	395100	410	33	7350			
U	Onishi (1980)							270			39			1	6000	
Zn	Sheppard and Thibault (1990)	200	0.1	8000				2400	200	100000	1600	70	13000			
Zn	Radovanovic (1998)													57.5	26.6	78.8
Zn	Onishi (1980)							5160	4390	5930				850		

4.2 Riparian Zone Data

The riparian zone model calculates the concentration of contaminants in soil and water in and around seeps on the edge of the river. Two sets of data are required for this model – dilution factors for the mixing of ground water and river water and distribution coefficients (K_d's) for water to soil partitioning of contaminants.

4.2.1 Proportion of River Water in Riverbank Seepage

Three approaches have been taken to develop an estimate for the proportion of river water in riverbank seepage (i.e., dilution of near-river groundwater by infiltrating river water). First, two sets of from the 100-H Area were used to calculate the proportion of river water in bank seepage at hourly intervals, at two seepage sites. Second, field samples from seepage, near-river wells, and the adjacent river were collected in October 1991 along the shoreline from 100-B to 100-F. An average for each sample type was used to calculate the proportion of river water in seepage. Third, all available seepage specific conductance measurements were assembled and compared to assumed "end points" for groundwater and river water.

4.2.1.1 Hourly Data from 100-H Area Seeps

Set 1: Seep SH-153-1: The first analysis is for specific conductance measurements made at seep SH-153-1 between June 16 and 29, 1993. Hourly measurements were recorded simultaneously for the seep, a nearby monitoring well (199-H4-11), and the adjacent river, resulting in 312 records. The proportion of river water in the seepage was calculated for each hourly interval. The average value is **79%** river water, with a standard deviation of 21%.

Seep SH-153-1 is located along the cobbly riparian zone immediately downstream from the 100-H outfall spillway. The seepage is most likely along a preferential pathway across the beach, perhaps as the result of a former pipeline route. A specific conductance probe was buried in the cobbles of this seepage site. The site is believed to be well-flushed by river water during periods of moderate-to-high river stage. The river stage during late June 1993 represented moderate flow, with a range between 100,000 and 120,000 cfs, as estimated from Priest Rapids Dam outflow.

Because this site is well flushed by river water on a regular basis, it is probably not the most representative site for assessing dilution by river water.

Set 2: Seep SH-152-2: The second analysis is for specific conductance data collected at seep SH-152-2 between August 18 and September 20, 1995. Again, hourly data for the seep, monitoring well 199-H4-11, and the adjacent river were used to calculate the proportion of river water in the seepage, with 779 records available. The average value is **55%** river water, with a standard deviation of 13%.

This seepage emanates from the concrete spillway apron associated with the 100-H outfall structure. The flow is much stronger than at seep SH-153-1 located just downstream. Again, a preferential pathway is suspected for this seepage, with the engineered backfill associated with the reactor coolant outfall structure being the suspected cause. Water emanating from this seep has characteristics similar to groundwater observed in well 199-H4-4. Because of the outfall structure, the alongshore entrainment of river water is minimized; mixing probably occurs primarily as a consequence of in-and-out movement of river water.

4.2.1.2 Shoreline Data from 100-B to 100-F, October 1991 Field Survey

Water samples were collected from riverbank seepage sites and the adjacent river along the 100 Areas as part of a field investigation under CERCLA in fall 1991 (DOE/RL-92-12). Specific conductance values for these samples, along with specific conductance values for monitoring wells located near each seepage site, were averaged. The proportion of river water in the seepage was then calculated using the average specific conductances for groundwater, seepage, and river water:

Sample from:	**Average Conductance (uS/cm)**	**Standard Deviation (uS/cm)**	**Number of Records**
Groundwater	418	249	155
Seepage	236	63	28
Nearshore River	110	11	25

Using these averages for the endpoints, the proportion of river water in seepage is **59%**. During fall 1991, the river was at its seasonal low discharge level. During this seasonal period, riverbank seepage should be least influenced by the infiltration of river water compared to other times of the year.

4.2.1.3 Riverbank Seepage Specific Conductance for All Seeps and "Typical" River and Groundwater Specific Conductance

Specific conductance values for riverbank seepage samples collected between September 1991 and November 2000 were assembled into one file. The sample set is biased toward the fall seasonal cycle, and toward the 100 Areas, because that is when and where most riverbank seepage sampling occurs. Obvious outliers were removed from the data set. The average specific conductance for 178 records is 258 uS/cm, with a standard deviation of 77 uS/cm. This average was then compared to typical average specific conductance values for groundwater and the river:

Proportion of River Water in Riverbank Seepage, Based on an Average Specific Conductance for Seepage of 258 uS/cm (Standard Deviation = 77 uS/cm for 178 samples)			
Endpoint Specific Conductance	***GW = 350***	***GW = 400***	***GW = 450***
RVR = 100	37%	47%	55%
RVR = 130	42%	53%	60%
RVR = 150	46%	57%	64%

The specific conductance for nearshore river water samples remains fairly constant between 120 and 130 uS/cm for most of the Hanford Reach shoreline. Where not affected by contamination (which typically increases the specific conductance), groundwater from saturated Hanford gravels is typically in the 400 to 450 uS/cm range, and from saturated Ringold Unit E sediments in the 350 to 400 uS/cm range. These two saturated units represent the aquifer near the river in the 100 Areas.

If a single value for dilution were to be selected from this matrix, assuming a river endpoint of 130 uS/cm and a groundwater endpoint of 400 uS/cm seems reasonable. This results in the proportion of river water in seepage of **53%**.

The riparian zone locations were all chosen to be 5 meters from the edge of the river. The inputs to the riparian zone code RIPSAC require the proportion of groundwater in the seepage. This value is computed as the proportion of river water seepage subtracted from one. A triangular distribution was chosen to model the data. The minimum value was 0.36 (representing the data for GW=450 and RVR=150 in the table above), the mode was 0.47 (representing the data for GW=400 and RVR=130), and the maximum was 0.63 (representing the data for GW=350 and RVR=100).

4.2.2 Distribution Coefficient (K_d) Values in the Riparian Zone

A statistical description of the distribution coefficient (K_d) for each contaminant is required for the riparian zone model. The same statistical descriptions were used in this model and the vadose zone transport model. The statistical descriptions are provided in the vadose zone data package. The riparian zone model used only the K_d's for groundwater (category F1) for the Waste Chemistry/Source Category 6: "Low Organic/Low Salt/Near Neutral" waste.

4.3 Background Data

Information on the suspended sediment and contaminant concentrations entering the modeled region from up stream and tributaries is needed to evaluate Hanford's incremental impact on the Columbia River.

4.3.1 Suspended Sediment

The background suspended sediment data were obtained from the USGS National Stream Water Quality Network (NASQAN) web site:

http://water.usgs.gov/nasqan.

Data for Columbia River at Vernita Bridge, Yakima River at Kiona and the Snake River at Burbank were downloaded and used as model boundary conditions. Each dataset included information on numerous aspects of water quality including temperature, conductance, DO, pH, alkalinity, dissolved constituents and suspended sediment concentrations. These data consisted of several measurements per year starting in 1996. All of the suspended sediment concentration data were averaged for each location to estimate the background suspended sediment concentration. The results are shown in Table 2.

Table 2: Suspended Sediment Concentrations used (kg/m^3)

Location	1964-1966	1990-2000
Vernita Bridge	0.00375	0.00375
Yakima	0.06	0.06
Snake	0.016	0.016

4.3.2 Radionuclide Data

Background radionuclide data for surface water and sediment samples were obtained from 5-year geometric means for 1990-1995 taken from the CRCIA Project[1]. The only surface water values available for the constituents studied here were tritium (3.97E-8 Ci/m^3) and uranium-238 (1.73E-10 Ci/m^3). Uranium-238 sediment sample concentrations were available for the Columbia (7.9E-10 Ci/kg), Snake (2.8E-10 Ci/kg), and Yakima (2.0E-10 Ci/kg). For the Columbia River the surface water uranium-238 concentrations were partitioned using the test K_d values (20, 100, 1000, and 4000 ml/g) to generate the surface water particulate and dissolved boundary conditions for each run. Since no surface water concentrations existed for the Yakima and Snake Rivers, the suspended particulate concentration of uranium-238 was computed as the product of the suspended sediment concentration (kg/m^3) and the concentration of uranium-238 in the sediment samples (Ci/kg). These data are discussed further and presented in the description of history matching results for the Columbia River.

Data on radionuclide inputs to the river were also required to perform the history matching model runs. Chromium-51 and zinc-65 inputs to the river from reactor releases in the 1960s were obtained from Walters et al. 1994 (http://www.bhi-erc.com/projects/vadose/sac/sacdocs.htm - Cr-all_reactors.pdf, Zn-all_reactors.pdf). The input data for the groundwater influx of tritium and uranium-238 were calculated based on groundwater concentrations and water table elevations presented in Hanford Site Groundwater Monitoring Reports from 1990-1998[2] (http://www.bhi-erc.com/projects/vadose/sac/sacdocs.htm - U-allpts.pdf, H3-allpts.pdf).

[1] Values were obtained from Terry Miley, Pacific Northwest National Laboratory, Richland, Washington
[2] Values calculated by Paul Thorne, Pacific Northwest National Laboratory, Richland, Washington

Monitoring data on radionuclide concentrations in the river were used to assess the performance of the fate and transport component of the model by comparison to the results of the history matching runs. Data on downstream concentrations of chromium-51 and zinc-65 at the 300-Area, Richland Pump House, Pasco, and the McNary forebay were obtained from Walters et al. 1994 data. The simulated tritium and uranium-238 concentrations were compared to monitoring data from the COC database at the 300-Area and Richland Pump House[3]. The results of these comparisons are presented graphically and assessed statistically in the description of Columbia River history matching results.

4.4 Methods of Estimating Uncertainty

The uncertainty in the input data, the K_d values, and the lateral diffusion coefficients was addressed by using high and low estimates of each. High and low estimates of the chromium-51 and zinc-65 data were generated by computing the standard deviation of the stochastic values reported in Walters et al. 1994. Using this standard deviation new data were computed by adding one standard deviation for the high estimates and subtracting one standard deviation for the low estimate (http://www.bhi-erc.com/projects/vadose/sac/sacdocs.htm - Cr_high-all_reactors.pdf, Cr_low-all_reactors.pdf, Zn_high-all_reactors.pdf, Zn_low-all_reactors.pdf). High and low estimates of tritium and uranium-238 were generated by incorporating the uncertainty of the amount of these constituents entering the river through groundwater influx[4] (http://www.bhi-erc.com/projects/vadose/sac/sacdocs.htm - U-allpts_high.pdf, U-allpts_low.pdf, H3-allpts_high.pdf, H3-allpts_low.pdf). These uncertainties were based on uncertainty in the plume thickness, concentration in the groundwater and transport rate (k). Uncertainty in the K_d values was assessed by using a wide range for each constituent based on the values found in the literature. The values used and the corresponding results are presented in the History Matching Document. Lateral diffusion coefficient values (k_y) ranging from <1 to 10 were used and best results were achieved using k_y values of approximately 5-10.

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[3] Data obtained from Greg Patton and Terry Miley, Pacific Northwest National Laboratory, Richland, Washington

[4] Uncertainties obtained fro Paul Thorne, Pacific Northwest National Laboratory, Richland, Washington

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